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THE OCULO-MOTOR CENTRES AND THEIR CO-ORDINATORS.

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Address delivered before the Philadelphia Neurological Society.

I KNOW of no subject within the domain of neuro-anatomy, whose consideration is at the present moment so well timed, being replete with clinically suggestive facts, as that of the cell-nests which are connected with the third, fourth and sixth cranial nerves, together with the inter-nidal tracts which unite them in automatic co-ordination. Recent researches have brought our knowledge up to a point of almost ideal exactitude. Inasmuch as my collection of specimens enables me to illustrate several of these points, I have selected this subject in response to the kind invitation of your council.

The intrinsic anatomy of the cell nests of the fourth and sixth nerves is comparatively simple, and I shall refer to these only in so far as they are involved in the binocular mechanism. That of the third pair is more complex. There is strictly speaking no oculo-motor nucleus, in the sense in which Meynert and his followers use the term ; that is, no single undifferentiated cell nest, on each side of the median line, giving origin to the oculo-motor nerve of the corresponding side, and to nothing else. The first blow dealt this view was given by v. Gudden,[1] who found on des-

[1] Ueber die Kerne des Augenbewegungsnerven. Tageblatt der 54ten Versammlung der Aerzte und Naturforscher in Salzburg, 1881, p. 186.

troying one third pair, that the ensuing nucleur elimination was not limited to one side, but involved both sides. He was thus able to distinguish *two* nidi for each oculo-motor ; one of these, representing a decussated origin, is situated meso-caudal (in the rabbit) the other, and main nest, is found lateral, and gives origin to those fibres of the third pair which remain on the same side. I have been able to confirm this result with some slight and immaterial modifications in the cat.[1] On examining more minutely, it is seen that it is the innermost and most posterior rootlets of the third pair, that cross the median line and have a decussated origin.

Now, pathological observations in the case of man[2] show that it is precisely these rootlets which carry the innervation of the rectus internus. The division of the third pair supplying that muscle must be therefore regarded as bearing a similar relation to the division supplying the levator palpebræ, rectus superior, inferior, obliquus inferior, sphincter iridis, and musculus ciliaris, which the decussated portion of the optic nerve bears to its non-decussated division. There is, however, this noteworthy inverse relation between the optic and oculo-motor nerves. The lower forms with total decussation of the optic nerves (and consequent non-identity of the retinal fields) appear to have no decussated origin for the nerve fibres supplying the rectus internus.[3] Those with a partial decussation of the optic nerves, do have such a decussated origin for the nerve fibres

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[1] Neurologisches Centralblatt, 1885, p. 246. Vorlaufige Mittheilung uber einige durch die Atrophie Methode erzielte Resultate.

[2] Kahler–Pick. Archiv. f. Psychiatrie, X, p. 334.

Among the cases not generally cited which support this view, is one by Millingen, where a focus of disease situated to the right of the Aqueduct pressed close on the median line of the central tubular gray of that region. There had been during life spastic (irritative?) contracture of both internal recti. They would have to be situated near together, and mutually near the median plane, to account for this observation.

[3] I can find no indications thereof in the sea or fresh-water turtles (*Thallasochelys midas* and *Nannemys guttata*). The partial decussatian of the chiasm, the decussation of the rectus internus fibres, and the bilateral reflex reaction of the orbicularis palpebrarum go hand in hand.

supplying the rectus internus. In other words, there is a parallelism in development between the decussated division

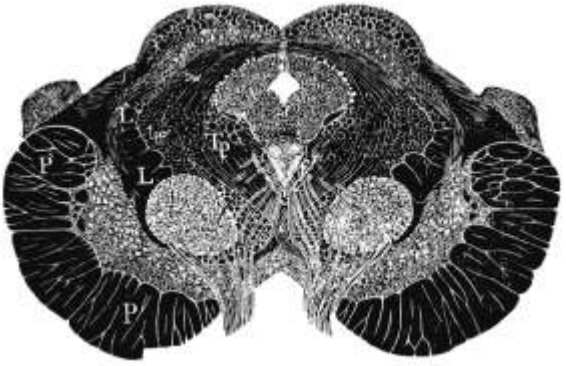

FIGURE I.—Transsection through human meso-cephalon, the clear spaces at the base of the aqueduct-gray represents the sub-nests of the venlo-motor nidus.

of the third pair and the non-decussated division of the second pair, which is in harmony with physiological requirements, and, if I may use such a term, anatomical convenience.[1]

This is not the only differentiation of the nuclear masses connected with the third pair. Further cephalad near the median line there is in man, a closely crowded cell mass, with a dense molecular basis which is in most levels sharply demarcated, and in others (as far as I am able to determine individual differences exist) sends out a lateral process.[2] In caudal levels it is a vertical column parallel to the raphe; in cephalic levels the lateral extension preponderates, the vertical column shrinks and eventually it becomes a mere appendix to the transverse oval mass into which this extension becomes as it were inflated.

[1] The philosophy of this mechanism will be considered in connection with the posterior longitudinal fasciculus of the tegmentum.

[2] Westphal, who is the first to accurately describe this sub-nidus, says that no indications can be found in any illustrations extant, of its prior recognition. In the accompanying wood-cut, which has seen service in two of the author's papers (JOURNAL OF NERVOUS AND MENTAL DISEASE, 1879–1880, and *N. Y. Medical Record*, Oct. 25, 1884), it will, however, be seen that the distinction had been recognized, though less accurately, and without any physiological deduction, or reference in the text. See Westphal, "Archiv. f. Psychiatrie," *loc. cit.*

Westphal, who first sharply demarcated this sub-nucleus, adduces clinical and anatomical facts to prove that it is connected with the innervation of the inner muscles of the eye, that is, the ciliary or the iris sphincter, or both. Before proceeding to discuss this exceedingly plausible view, permit me to describe in detail the cell-nests, and their relations to root and other fibres, as derived from a study of three sets of trans-sections of the human isthmus, one of which was a complete one.

In order to simplify matters I will distinguish four transsection levels, designating them respectively, *A*, *B*, *C* and *D* in the cephalo-caudal direction.

(*A*) The general contour of the aqueduct-gray is drawn ventrad into a very sharp apex. In its dorsal part it is materially encroached upon by the post-commissura. Powerful fibre bundles surround its margin,[1] occasionally breaking into its lateral contour, but mostly accumulating latero-ventrad to form the posterior longitudinal fasciculus, which in this level is extremely small as contrasted with the dimension it has in field *D*.

Cells.—The cells of this level are of intermediate dimensions, they are mainly accumulated in a single mass, which follows in contour the latero-ventral outline of the central tubular gray. They are parallel to this contour with their long axes. They do not stain as deeply in carmine as those of levels *B*, *C* and *D*. As we progress caudad they become more closely crowded, they appear smaller, but more distinctly stained, and the basis substance assumes more of the transparent gelatinous consistency, hence staining deeply in carmine.

Intra-nidal Fibres.—The medullated fibres are limited to the lateral angle of the aqueduct-gray, just ventrad of which they break into it. They appear to terminate in and

[1] It is their existence which induced Darkschewitsch (Pfluger's Archiv. XXXVIII. and Neurol. Centralblatt, 1885, No. 5, p. 100), to predicate a connex between the post-commissura and the oculo-motor nuclei, particularly regarding it as a path for the light-reflex, a view which is opposed by the excellent development of this commissure in animals with rudimentary eyeballs, and the absence of any lesion in it, in cases where there was reflex iridoplegia. (Moeli, Arch. f. Psych., XVIII., p. 31.)

around the dorso-lateral extension of the cell mass just described.

Posterior Longitudinal Fasciculus.—This important bundle can be distinctly seen to be built up by arched fibres coming from dorsad, circling round the lateral angle of the aqueduct-gray, ventro-mesad. They have the same derivation, apparently, as the intra-nidal fibres of this level.

Oculo-motor Rootlets.—These are as yet few, and in the cephalic sections of this level entirely absent. The most cephalic rootlet of the third pair, discoverable in a perfect series of sections from man is directly derived from the most mesal bundle of the posterior longitudinal fasciculus. It is the most cephalic and at the same time a mesal rootlet of that nerve, which has this origin. It is in caudal levels joined by fibers derived apparently from the nidus of cells above spoken of.

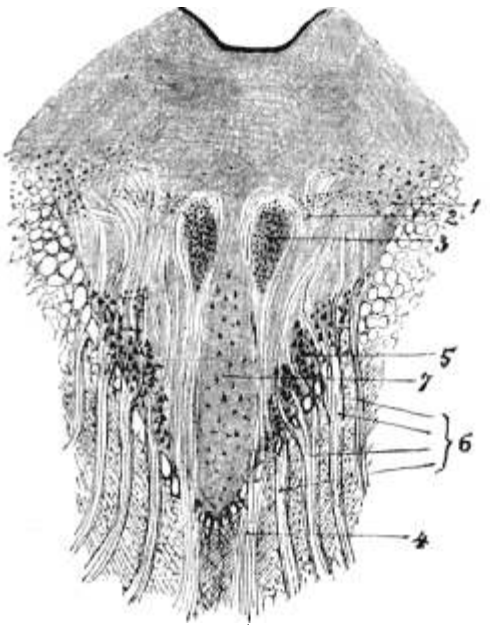

FIGURE II.– Transaction in second fifth of human oculo-motor nidus. 1. Lateral division of main nidus; probable center of levator palpebrae. 2. Fibres ectad of Westphal's nidus. 3. Westphal's nidus. 4. Emerging rootlets of III. pair, from fibres surrounding and entering that nidus. 5. Main portion of main nidus. 6. Rootlets of III. pair thence emerging. 7. Sagattil nidus.

(*B*) As we proceed caudad, the beautiful circular dorsal contour of the aqueduct-gray becomes established, the post-commissura no longer intruding. A lateral angle becomes more prominent, and the transverse diameter of the area becomes greater. At the same time the ventral prolongation becomes shortened. The demarcation is more distinct, the posterior longitudinal fasciculus forming its boundary even to and through the raphe.

Cells.—Two distinct nests can be recognized; one bordering directly on the posterior fascicle. The other, as yet the larger, corresponding to Westphal's nidus, is more mesal and slightly dorsal. Its cells are smaller, closely crowded, and become more so the more caudal we pass. The lateral mass is of larger cells. It grows larger as we pass caudad. I shall designate them respectively as Westphal's and the main nidus.

(*a*) *Westphal's nidus.*—From being parallel to the lateral contour of the ventral half of the aqueduct-gray, and separated by a considerable interval from its fellow, which it approaches only with its ventro-mesal extension, it becomes shaped like an inverted letter L, the two together occupying this relation ⅂⌐. It is the lateral extension which is occasionaly cut off from the main mass and which Westphal designates as a separate nidus, (his lateral cell-group). Histologically it is exactly the same as the remainder of Westphal's nidus.

(*b*) *Main nidus.*—Closely applied to the contour of the posterior fasciculus, extending into the peninsulas of gray matter which the aqueduct-gray detaches betwixt its bundles, this cell-nest gradually increases caudad,as Westphal's nest decreases. It extends nearer and nearer to the median line, but never quite reaches it, at least not as a compact cell-mass. It is everywhere demarcated from Westphal's nest, and all other cell-groups by the powerful fibre-arch to be described.

Intra-nidal Fibers.—The large intrusion of fibres noted in level *A* increases and arches completely round the main nidus. It sends off numerous detachments into it. On the whole it may be compared to a horse-shoe joined at either

end, apparently, to the most ectal and mesal rootlets of the third pair, its arch resting on the main nucleus, its fibres fielding off the latter into various irregular columns and groups, resembling the sub-nests of the hypoglossal, the facial and other motor nerve origins. I shall henceforth designate this as the *great intra-nidal fibre arch.*

In and bordering on the middle line of the aqueduct-gray, are straight fibres which take the following three courses, dorsal: 1. Parallel to the middle line, coursing along the mesal aspect of Westphal's nest and arching ectal round its dorsal aspect. 2. Parallel to the middle line, ectal of those just described, and directly abutting on that nest. 3. Starts parallel to median line, then arch over between the ectal aspect of Westphal's nest and the great intra-nidal fibre-arch, with which it is confounded, to arch round the ectal prolongation of Westphal's nest or even to break into it, so as to cut off one, sometimes two, islands.

Posterior longitudinal fasciculus. — This bundle has nearly attained its full dimensions, it extends to the middle line, across which, but for interruption by connective tissue septa, it is continuous.

Rootlets.—The innermost rootlets of the third pair are in part, directly continuous with the fibers abutting on and encircling Westphal's cell-nest. The middle and ectal radicles are not necessarily derived from those divisions of the main cell-nest opposite which they appear to emerge, for individual fibres can be seen to meander quite a distance amongst and over the sub-nests before becoming lost. Some fibres appear—but it is impossible to establish this clearly—to emerge from the great intra-nidal fiber-arch.

(*C*) The aqueduct gray continues to becomes wider, and lower, the meso-caudal prolongation shrinking upwards; still there is a considerable prolongation between the two main masses of the posterior fasciculus, abutting the junction piece of the latter. At the lateral angle, where the "arched" (dorsal) and angular (ventral) half of the aqueduct joins, fibres appear to originate in a lateral mass of

cells shaped like those of the oculo-motor nidus,[1] and running lateral and slightly caudal, after a direct course, become lost. Of their significance nothing is known, and they are excluded from consideration here.

Cell nests.—There are three, the main nest, attaining its full development, a sagittal nest, between the two main nests, and the last residue of the disappearing nests of Westphal.

(*a*) *Westphal's nest* is represented by an oval mass, whose long axis is parallel to its fellow from which it is separated by a considerable interval.

Main nest—same character as in level B, the peninsular extensions into the posterior fasciculus are in some individuals very large.

Sagittal nest.—The ventral extension of the gray matter contains cells shaped like those of the main nest, and demarcated from it by fibres passing on either side ventro-dorsal to the relics of Westphal's nest.

In addition to these cell nests, the small scattered angular nerve cells which are found in all levels in the caudal or angular half of the aqueduct-gray, become larger, and near the floor of the aqueduct present an accumulation which is quite distinct, and exactly in the median line.

Intra-nidal fibres.—(*a*) The *great intra-nidal fibre arch* becomes more and more individualized as we proceed caudal, and the main nucleus becomes distinctly isolated and often driven out of the contour of the central tubular gray by it. It is plexiform in arrangement, its connex with the great rootlets of the third pair is very distinct.

b Westphal's fibre field is represented by a vertical column of fibres, to whose dorsal end Westphal's nest is attattached like a stone enclosed in a sling. It is very compact, but ventrad becomes less so—probably by gradual passage to cephalic levels. The symmetrical columns form the lateral boundary of the sagittal cell-nest.

(*c*) *The decussated fibre field.*—There is a distinct decus-

[1] They might be confounded with the lateral group of Westphal's nidus, but they do not appear in the same level, are not continuous therewith, and are larger and less crowded.

sation of fibres which appear to originate in the cells of the sagittal nest. This decussation is not symmetrical. In one level, the bundle from left to right, in the next, that from right to left preponderates. They extend but a short distance across the median line with their cell origins ; the crossed part becomes lost in the great arched intra-nidal field.

(*D*) The angular part of the aqueduct gray has contracted so much that but a small part falls below a line connecting the "angles." The ventral apex is still present, but the lateral contour has become gradually tilted, so as to be nearly horizontal.

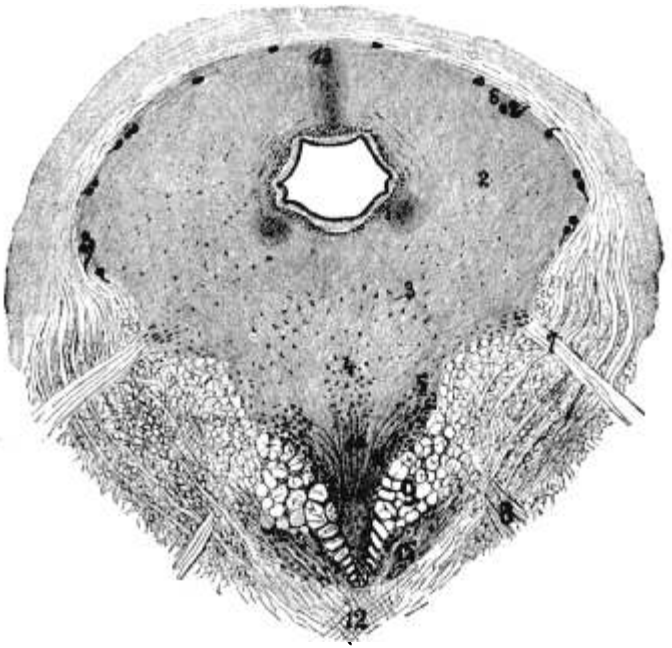

FIGURE III.—Section through more caudal level of human oculo-motor nidus. 7. Rootlets from the subdivision of main nidus, probably representing levator palpebra. 12. Fountain-like decussation of tegmentum.

1. Molecular mass of raphe. 6. Cells of descending trigeminal origin. 3. Scattered cells. 5. Main nidus. 9. Posterior longitudinal fasciculus. 10. Sagittal nidus. 11. Great intra nidal fibre arch. The molecular masses near either angle of the floor of the aqueduct may represent the interoptic ganglia of the reptilia.

Cell nests.—Aside from the diffuse small cells, there is but one, and that is the main nest. It has become almost

isolated from the aqueduct gray by the great intra-nidal fibre arch, which here shows a diminution, to eventually disappear, before the nucleus does so. The distinction between the main nucleus and the common gray of the aqueduct can however, easily be made. It is less gelatinous, and its basic substance stains less deeply in carmine. Its cells are the largest in the oculo-motor nidus. It is intimately connected with the septa of the posterior fasciculus, *accessory bundles of which appear in the cross-section of this nidus, and in sagittal sections appear to proceed directly out of it.*

Rootlets.—There are no rootlets in these levels, although the large nuclear mass above spoken of extends a considerable distance caudad.

Intra-nidal fibre fields.—The great arched field disappears at the cephalic part of the insulated division of the main nest just described. There are numerous fibres apparently passing from one main nest to the other.

Summing up the foregoing, the topography of the cell nests in the angular division of the aqueduct gray may be stated to be as follows: First, a diffuse formation of small angular cells, loosely scattered, or as in level *c*, showing an accumulation ventrad of the aqueduct. Second, a distinct cell nest, successively laurel leaf, inverted L, and oval shaped, with small crowded cells imbedded in dense molecular substance, which is at once a dorso-mesal and the most cephalic. This is the one discovered by Westphal. Third, a large complex nucleus, beginning far cephalad, but yet caudad of the cephalic end of Westphal's nucleus, closely applied to the posterior fasciculus,increasing caudad, finally almost isolated from its parent gray, and ultimately lost among the septa of the posterior fasciculus. This is the main or proper cell-nest. Fourth, a sagittal cell-nest, not separable into symmetrical halves, which begins in the third fifth and ends before the last fifth of the cephalo-caudal extent of the main nest.

The main part of the oculo-motor, namely, all except its most cephalo-mesal and caudo-mesal fibres, originates from the *main nidus*. Its most cephalo-mesal fibres origin-

ate from the *nidus of Westphal.* As to its caudo-mesal fibres there is some doubt, though the probability is that they originate from the *sagittal nidus.* It is noteworthy that no oculo-motor rootlets originate from the posterior (semi-isolated) division of the main nest, imbedded in the posterior fasciculus. I believe this mass can be identified with those cells to which Mendel traced the orbicularis oculi fibers of the facial nerve, and will in the sequel advance reasons for this view.

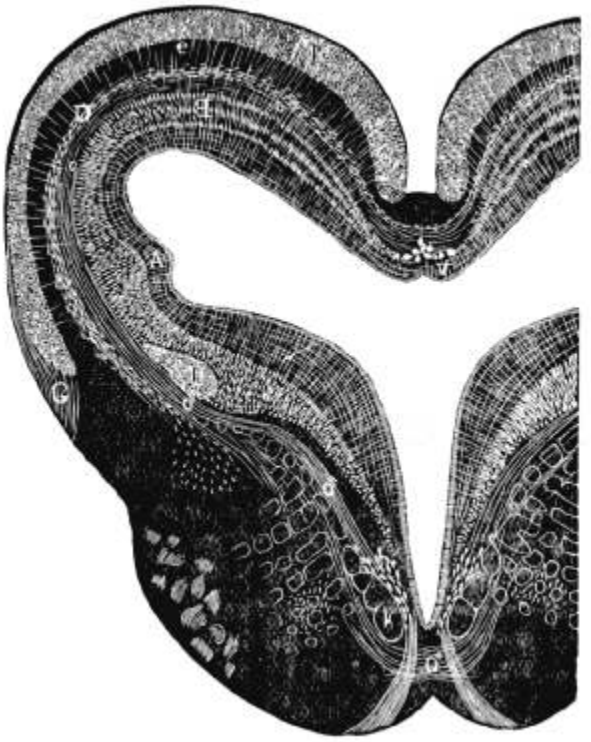

FIGURE IV.—Transsection of mesen-cephalon of fresh-water turtle.

COMPARATIVE DEVELOPMENT OF THE OCULO-MOTOR NUCLEI AND FIBRE TRACTS.

In the reptiles generally,[1] there is but little, if any, indi-

[1] The sea-turtle, fresh-water turtles, snakes and Sheltopazik which I have examined.

cation of a differentiation of these cell-nests of the third pair. The ventral part of the aqueduct-gray, which in these animals is drawn out in a long attenuated area on either side of the mesocœlian slit, contains a number of scattered elements shaped like typical motor cells, and from which the fibres of the third pair can be traced with a distinctness seldom found in mammals. Some indication of individualization is found in a group lying most ventral, where the aqueduct-gray often shows a slight swelling on it. Dorsal the cells become smaller and are followed by the ordinary minute elements characterizing the outer part of the aqueduct-gray of these animals. In some Saurians like the Anolis and Iguana, the nuclei are better developed, and it is particularly the cell-nest of the trochlearis that is beautifully individualized.[1]

In birds the nucleus of the third pair is very large. In a series of sections (sagittal) from the ostrich, I can distinguish two superimposed strata of cells, which are probably the expression of as many lateral extensions of the central tubular gray; one of these is interradicular and ventrad of the posterior fasciculus. In all the sauropsida the posterior longitudinal fasciculus is very distinct, and in some (chelydra) an uninterrupted course of single axis cylinders can be traced to the fundamental anterior column of the spinal cord.[2] In all, its connection with the nucleus of the third, fourth and fifth pairs is obvious. In none can its origin be traced much further forward than the anterior end of the oculo-motor nucleus. The fibres of most cephalic extent appear to be derived from the deep gray of the optici[3] (anterior pair of the corpora quadrigmina); succeeding fibers

[1] The cell-nests in the chamaleon would prove an interesting study. It is not impossible that the nest connected with the nictitating membrane may be discovered in some of the sauropsida.

[2] Osborn has shown me drawings from an amphibian brain in which this bundle is represented as giving off from its caudal extent a fibre to the horseshoe shaped root of the facial nerve, a noteworthy observation stated to be based on unmistakable appearances.

[3] Owing to the peculiar distortion of the mesencephalon in birds the optici are crowded latero-ventral. It is probably connected with this fact that the anterior end of the posterior fasciculus undergoes a marked curve ventrad.

originate or terminate in the nuclei of the oculo-motor system, and the remainder run into the spinal cord, as the deepest fibres of the anterior column.[1] These relations appear to be maintained in all higher vertebrates, including man. In the dog, cat, sea-lion and lion, the nuclei are disposed similarly to the plan which will be detailed when discussing my atrophy experiment. In a beautiful section parallel with the base of the brain of a dog, two distinct cell-nests can be readily distinguished. One of these is a slender column near the median line, and nearly fusing across it ; it extends further cephalad and ceases first caudad. Its posterior extremity is grasped, as it were, by the other large celled cell-nest. In other words, the main nidus opens out like the petals of a flower to enclose the root of its pistils, represented by the former small celled, or Westphal's cell-nest.[2] In the sea-lion the sagittal nuclei described by myself, is well-developed. In the dog a remarkable small celled, thickly crowded sagittal cell mass bisects the central tubular gray in the level of the posterior pair of the quadrigemina, and extends into the level of the trochlearis origin. I cannot establish its existence in man.

In the crepuscular bats the cell-nests of the oculo-motor system are very small, and the posterior fasciculus is attenuated. In the mole the nuclei are almost absent, and the fascicular is atrophic.[3] In the anthropoid apes alone, of all animals examined, is the anatomy of the oculo-motor cell-nests and their intranidal tracts approximately as complex as in man. This fact adds another to the numerous observations, which induced the writer, years ago,[4] to point out the erroneous nature of the view held by many, that in higher development the "intellectual" centres are developed at the expense of the reflex centres, or that the more perfect reflex mechanisms are to be sought for in lower

[1] Those nearest the gray substance of the base of the anterior horn, included between it, the anterior spinal commissura and the ventral fissure.

[2] The reader may be reminded at this point that in the dog, the accommodation pupil reaction is the reverse of the human.

[3] Ford, Archiv. f. Psychiatrie, vii., p. 421.

[4] Architecture and Mechanism of the Brain, JOURNAL OF NERVOUS AND MENTAL DISEASE, 1879–1880, pp. 45 and 67 of reprint.

forms. The nuclear anatomy of the spinal centres of the hypoglossal and facial nerves, and even if so blindly automatic a system as that of the ocular-motor mechanism, prove at every step that man is at the head of the vertebrata, not alone in regard to his central development, but also in the extent, complexity and intricacy of the reflex centres and their uniting fibre tracts.

The atrophy experiment I have referred to has been detailed in its general features elsewhere.[1] Suffice it to say that the left third pair was divided at its emergence from the crus, and that all the other oculo-motor nerves were normal. The left optic tract had been also divided. In the sequel I shall attempt to homologize the atrophied developed sub-nuclei with the human by giving the same names used in the above description of the human sub-nuclei.

(*a*) *Main nucleus.*—Normally developed in all levels on the right side. Present only in its most posterior division on the left side.

(*b*) *Sagittal nucleus.*—On the left side it is normally present, but on the right side of a line drawn from the ventral apex of the aqueduct to the raphe, few, and those very small, cells are found.

(*c*) *Westphal's nucleus.*—As I am uncertain about the homologies of this nucleus in the cat, though well developed in the dog, I reserve any opinion for the present.

(*d*) *Nucleus under aqueduct* symmetrically developed.

(*e*) *Intranidal fibres.*—These in my specimens of normal carnivora, as well as the experimental kitten, are more interlaced and less distinctly grouped in bundles than in man. In the level where the left sagittal and right main nucleus are in their main development, they are seen in large numbers extending dorsad and mesad of the right main, and across the median line into the left sagittal nucleus. Both classes of fibres enter the emerging rootlets of the right third pair.

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[1] JOURNAL OF NERVOUS AND MENTAL DISEASE, June, 1888, vol. xiii., No. 6, p. 349.

(*f*) *Posterior longitudinal fasciculns.*—In all higher levels a marked asymmetry is observed. In the upper level of the main nucleus it is absent on the operated side. With the appearance of the sagittal nidus, it is found on both sides, about half as large on the operated as on the unoperated side. At the lower end of the oculo-motor nidus, whose posterior division as stated is present on both sides, it is about two-thirds the area on the operated side, as compared with the other. It thus continues to the level of the abducens nidus caudad, of which a marked difference is not noticeable.

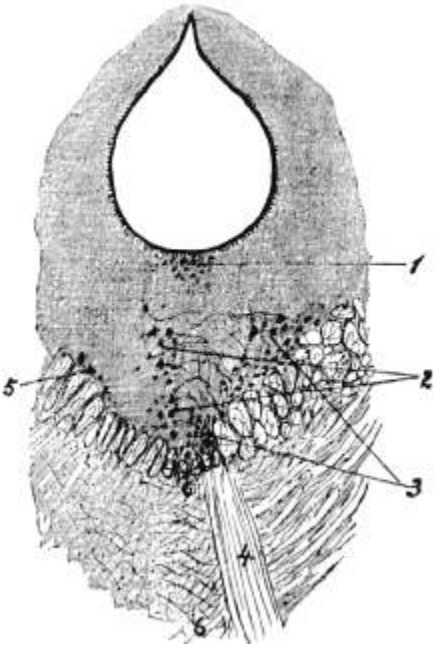

FIGURE V.—Transsection through oculo-motor nidus of cat, whose left third pair had been destroyed. 1. Subendymal cell mass. 2. Crossed nidus of third pair, (sagittal nidus). 3. Main or uncrossed nidus. 4. Intact right root. 5. Nidus symmetrically developed notwithstanding the unilateral destruction of the third pair, and identical with the nidal centre, eliminated by Mendel through peripherel destruction of the orbicularis palpebraerum. 6. Raphe.

In addition to these observations in normal human and comparative anatomy, as well as those derived from the atrophy method, I had the specimens of a case of organic central ophthalmoplegia partialis externa at my disposal, a

complete series of sections from which had been prepared jointly with Dr. N. E. Brill. My conclusions from these observations and the observations of others are subjoined under appropriate headings.

THE INTRA-OCULAR INNERVATIONS.

The rootlets for the pupillary and ciliary muscles.—Pathological observations show that lesions of the crus, involving those rootlets of the third pair which traverse the crus, produce paralysis of the outer eye muscles, but leave the inner ones intact. It is to be assumed from this that those anterior-most fibres which do not traverse the crus, or only reach it shortly before their exit, are related to pupillary and ciliary projection. Experimentally the complementary observation has been established. Dividing the anterior-most fibres of one third pair, eliminates accommodative power on the corresponding eye, leaving that of the other eye intact.[2]

The cell-nests from which rootlets for the pupil and ciliary muscles arise.—Pathological destruction of the central tubular gray of the posterior division of the third ventricle,[3] sclerotic induration with contiguous endymal hypertrophy,[4] and experimental interference[5] with the same region will destroy the light reflex of the pupil. In case the affection be unilateral, the loss of the light reflex is homolateral. Inasmuch as the retinal fibres mediating the light reflex do not run in the optic tract, but leave the optic nerve at the chiasm to plunge into the ventricular gray,[6] it appears reasonable to assume that the sub-nest of the oculo-motor nucleus, related to the pupillary movements must be situated far cephalad, in order to be most conveniently situated for the reception of the nidal end of the pupillary reflex arch. This view is strengthened by the observations just

[1] Oyon, cited from Gazette Medical de Paris, 1870, No. 47, by Wernicke. Gehunkrankheiten.

[2] Heuser-Volckers, Archiv. f. Ophthalmologic, xxiv., pp. 1–26.

[3] W. Sander, Archiv. f. Psychiatrie und neuenkrankheiten, p. 287.

[4] Our observation, unpublished.

[5] Bechtherew, Pfluger's Archiv., xxxi., 1883.

[6] Bechtherew, Neurologisches Centralblatt, 1883, No. 12.

cited, demonstrating the rootlets related to the intra-ocular movements to be most cephalic. There is one observation which enables us to limit the cephalic extent of the pupillary nidus more narrowly by exclusion. It is not situated much, if at all, in front of the trans-section level of the post-commissura, because lesion of the region in front when unilateral abolishes the light reflex of the corresponding eye, but it does not abolish consensual reaction on that eye.[1] We are also able to say that the pupillary nidus is homolatateral for each eye, as the lesions of the central, tubular gray,[2] or special rootlets, producing limited pupillary paresis, when unilateral were always on the same side as the symptom. But the strongest evidence in favor of the location of the sub-nest for the intra-ocular muscles is furnished by two cases, one in which there was practically total external ophthalmoplegia with preserved accommodation,[3] and the other in which there were gross disturbances in the innervation of all the external muscles of the eye except the right abducens and both superior obliques, also with preserved accommodation,[4] and in both of which the only unquestionably healthy cell-nests were Westphal's nidi, one on either side of the median line. At present we are only able to affirm with confidence that it is the nidal centre of accommodation. Its freedom from disease with preserved accommodation in the midst of ophthalmoplegia, its cephalic location, in topographical harmony with the results of electrical irritation,[5] and with the situation of the accommodative nerve-rootlets, all strongly support this view. We are unable to differentiate between such parts of this cell-nest, if any, which may be separately consigned to the ciliary and pupillary muscles.

THE EXTRA-OCULAR NIDAL CENTRES.

The rootlets related to the innervation of the internal rectus.—In a case where the most meso-caudal rootlets of

[1] Bechtherew, Pfluger's Arch. loc. cit.

[2] Sander, Arch. f. Psych. loc. cit.

[3] The case of Westphal already cited.

[4] The unpublished case of my own, elsewhere referred to.

[5] Hensen and Volckers, Graefé's Archiv., 1874, p. 1.

the third pair were destroyed in man, the paralysis was limited to the internal rectus muscle. The pupils were entirely unaffected.[1] This proves that the rootlets for the two are distinct. Indirectly it suggests that the respective nidi must be distinct, because the nest for pupillary innervation is homolateral, and that for the internal rectus is contralateral.

The nidal centre for the internal rectus.—The atrophy experiment of von Gudden in the rabbit, and the same experiment repeated in the case of the cat by the present writer, conclusively prove that there is a decussated origin for a part of the oculo-motor nerve. By exclusion, and by physiological deduction, we can prove that this cannot be the nidus of any other muscle than the internal rectus.

The nidal centre for the levator palpebræ.—All gross lesions of the main nidus produce ptosis. There is one observation of a limited lesion, a hemorrhage destroying the most lateral part of one main nucleus, with homolateral ptosis.[2] In another case of multiple paresis of the oculo-motor apparatus, marked left ptosis was associated with a macroscopic hemorrhagic focus,[3] destroying the most external sub-group of the main nest, in varying extent in its upper and middle levels. We may therefore assume the levator palpebræ to be represented in at least the middle altitude of the main nest in its most external division.

The nidal centre for the orbicularis palpebrarum.—The eyelid sphincter, under the reflex dominion of retinal impressions as it is, and intimately bound in associate innervation with certain extra-ocular muscles of the oculo-motor system,[4] is not, as has been heretofore thought, under the dominion of the *nidus facialis*. Mendel, by destroying the orbicular muscle in the new-born, produced atrophy in the

[1] Kahler-Pick, Archiv. f. Psych. in Nokikhtn., x., p. 334. Wallenbergh's case, if the accompanying drawings be correct, is opposed to the deductions which appear to follow so easily from Kahler-Pick's (Archiv. f. Psych., xix., p. 298, et seq.).

[2] Leube, Deutsches Archiv. f. Klinische Medizin, 1887, p. 219.

[3] My own unpublished case, herein repeatedly referred to.

[4] As evinced in the associated rolling motion of the eyeballs accompanying eye-closure.

most posterior division of the oculo-motor cell-nest. It is precisely this cell-nest which remains uninfluenced by destruction of the trunk of the third pair. The inference is obvious. There must be contained in the oculo-motor cell-nests one sub-nest whose emerging fibres are not included in the third pair. We know from other facts that there is

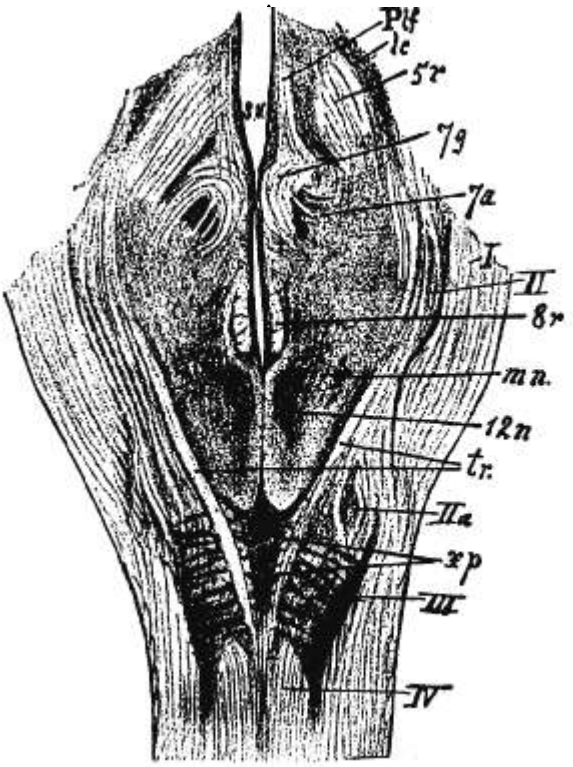

FIGURE VI.—Flatwise section of human isthmus. 7. g. Genu facialis. P. lf. Posterior longitudinal fasciculus. On the lettered side the transition of fibres from the latter to the former can be clearly seen.

one muscle represented in the seventh pair which is not represented in the nidus facialis.[1] The conclusion follows that an aberrant fasciculus from the oculo-motor nidus must join the emerging facial root. There is such a bundle from

[1] Detailed by Mendel, Neurologisches Centralblatt, 1887, No. 23.

the posterior longitudinal fasciculus to the genu facialis.

THE POSTERIOR LONGITUDINAL FASCICULUS.

This bundle contains a number of elements. (*a*) The bundle connecting the abducens nidus with the nidus of the internal rectus, and through which lateral associated movement of both eyeballs is effected. It was formerly thought necessary to assume a decussated course for this bundle.[2] But since it is now known that the nidus of the right internal rectus is on the same side as the nidus of the left external rectus, such a decussated course is no longer plausible.[3] The decussation is in the root-fibres of the third pair. (*b*) This fasciculus includes that part of the root of the facial nerve which represents the orbicularis palpebrarum. (*c*) It contains other fibres, which from their (probable) origin in the deep gray of the optic lobes and (almost certain) caudal termination in the nidal centres of the cervical muscles (head-rotation, etc.,) may be regarded as mediating that element in conjugated deviation of the eyes and head which is not mediated by the portion described under the caption *a*.

The oculo-motor mechanism is thus shown to have as complex an anatomical basis as the physiological study of its peripheral reactions would lead us to anticipate. And we are approaching a degree of accurate knowledge regarding the central seat of these reactions which approaches in exactitude and certainty the physiological observation itself.

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[1] The value of this observation is not diminished by the fact that the drawing was made and published before its significance was appreciated. It is simply an unbiassed record,

[2] Duval and Laborde.

[3] And is contradicted by the observations of J. Nussbaum, Wiener Medizinische Yahrbucher, 1887.